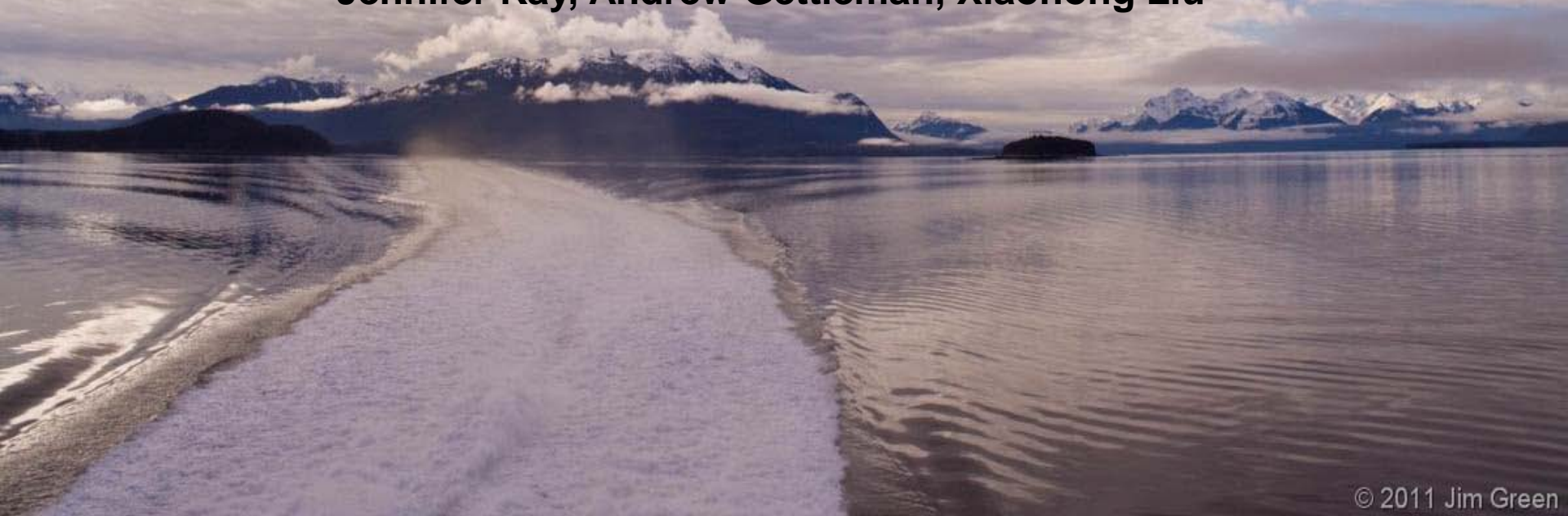


Impacts of CAM5 cloud microphysics on Arctic clouds and radiation

Jason M. English
NCAR Postdoctoral Researcher
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Thanks to Collaborators
Jennifer Kay, Andrew Gettleman, Xiaohong Liu



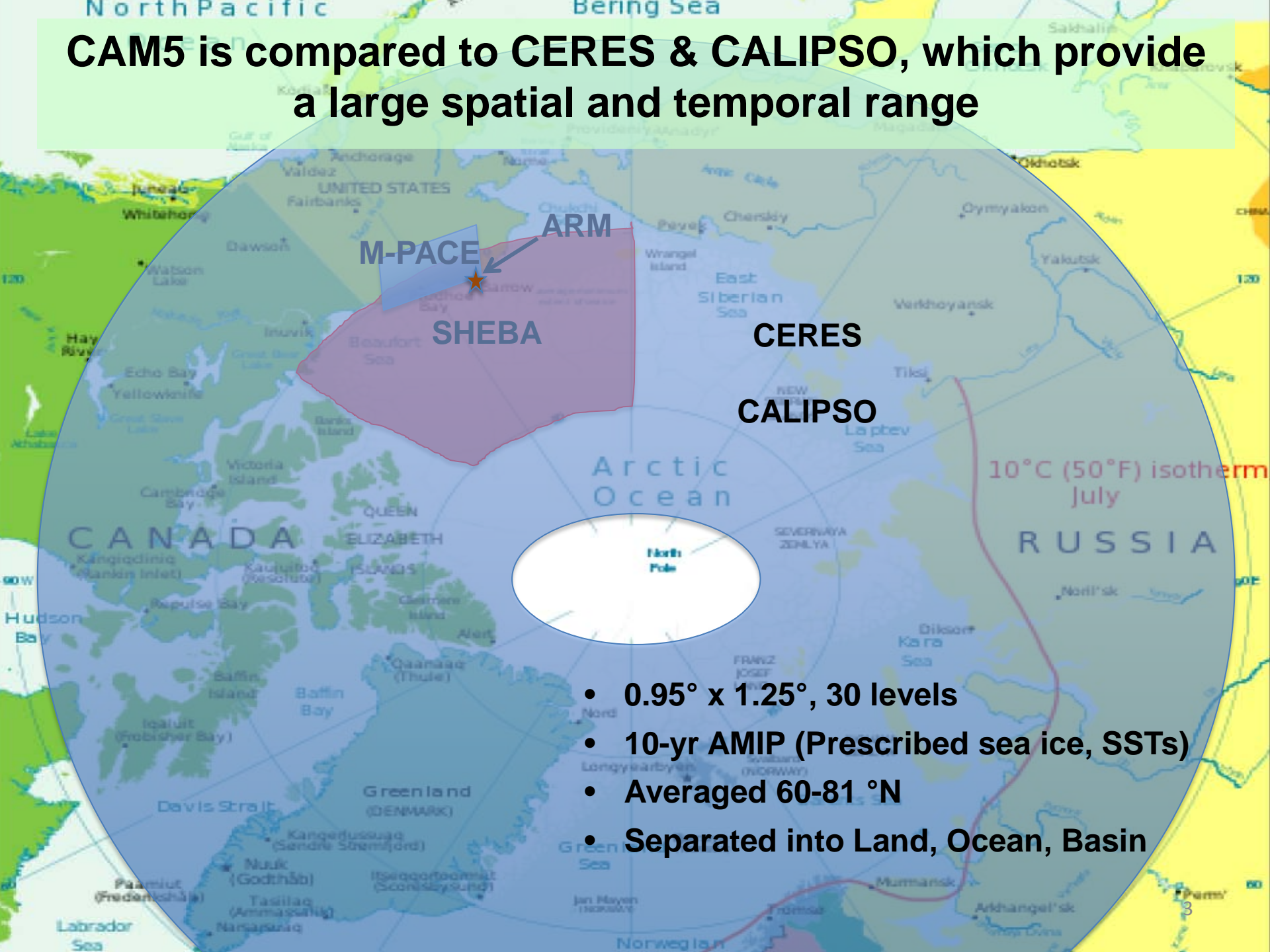
Motivation

- **Most climate models including CAM5 have biases in Arctic clouds (Insufficient cloud liquid; insufficient low clouds)**
- **This is due in part to a crude representation of mixed-phase cloud processes**

Goals

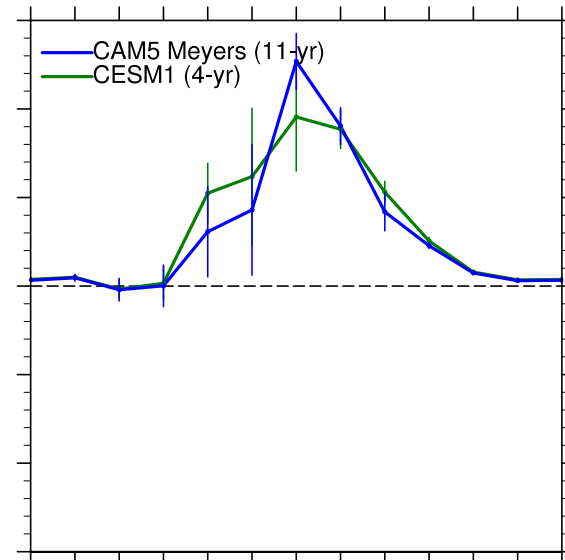
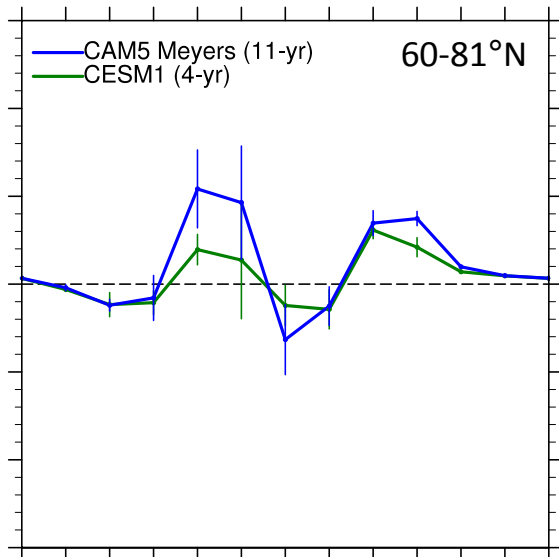
- **Conduct an Arctic basin-wide evaluation of CAM5 radiation biases and determine the contributions of clouds to these biases**
- **Implement improved mixed-phase ice nucleation schemes and evaluate their impacts on Arctic clouds and radiation**

CAM5 is compared to CERES & CALIPSO, which provide a large spatial and temporal range

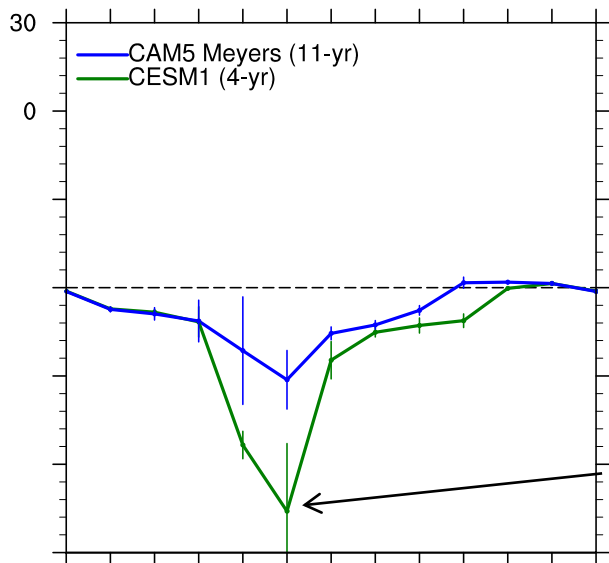


- $0.95^\circ \times 1.25^\circ$, 30 levels
- 10-yr AMIP (Prescribed sea ice, SSTs)
- Averaged 60-81 °N
- Separated into Land, Ocean, Basin

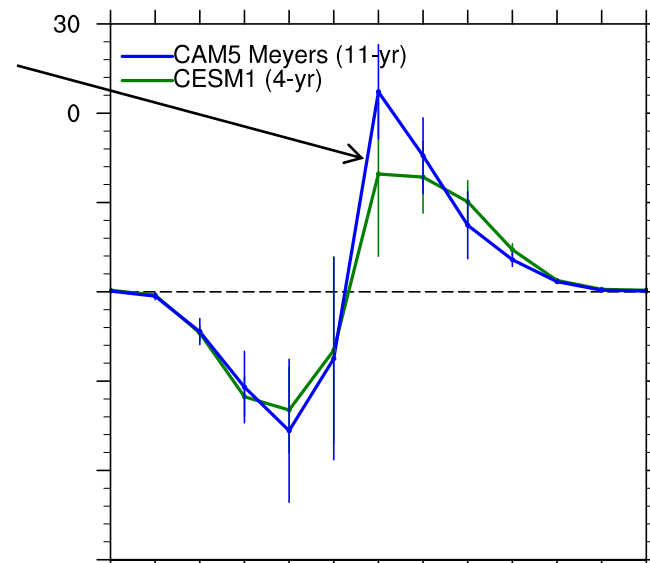
CAM5 TOA SW biases are mostly within 10 W m⁻² of CERES



Q: Why does CAM5 Summer clearsky SW over water swing from too low in spring to too high in summer?

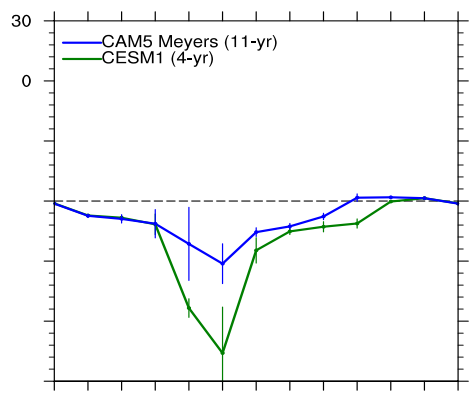


Q: Why is CAM5 Summer clearsky SW over land too low?

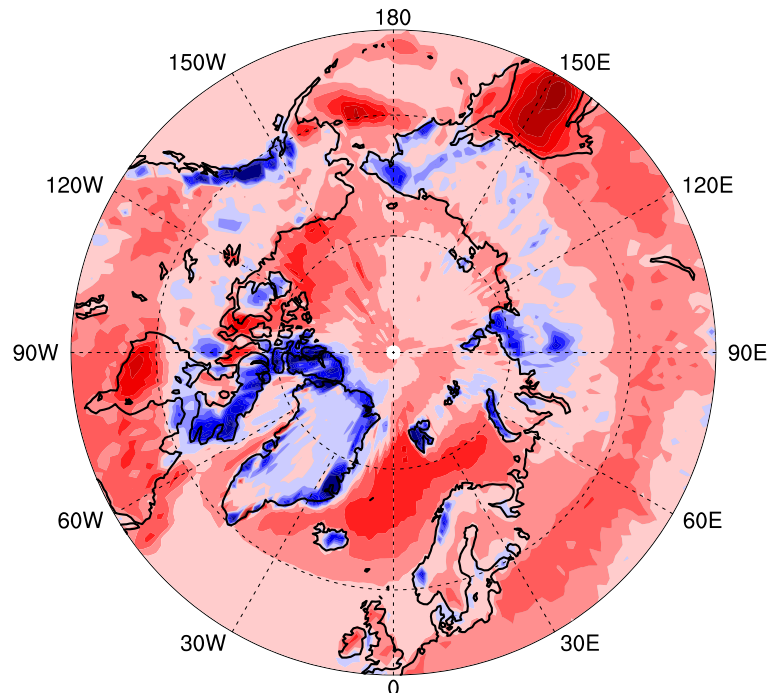


Q: Why is CAM5 Summer clearsky TOA SW over land too low?

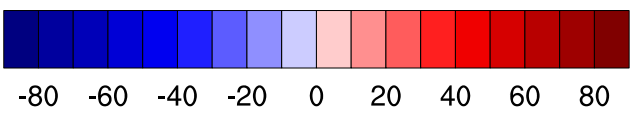
A: Model snow albedo is too high



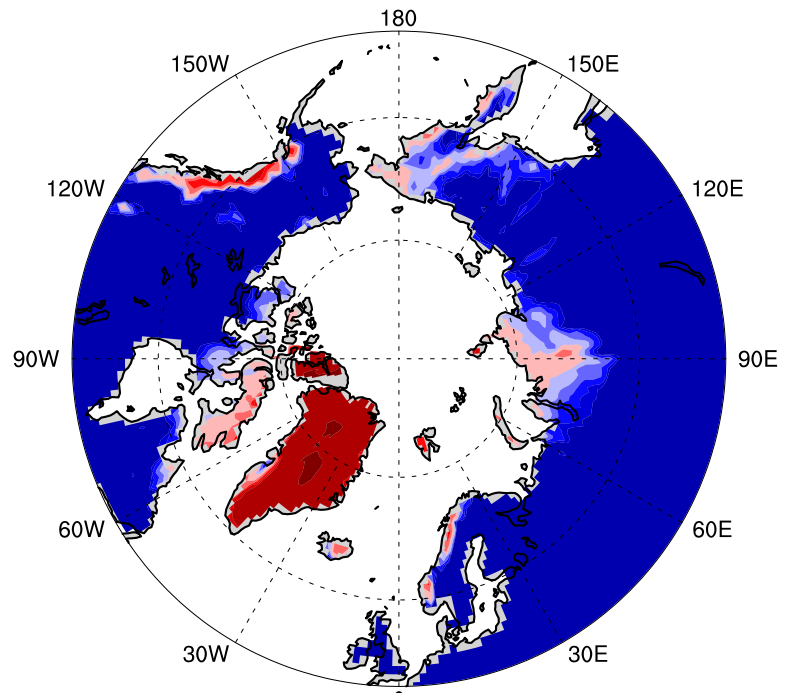
JJA Bias (CAM5 – CERES)



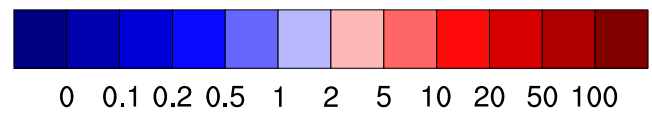
Clearsky net TOA SW ($W m^{-2}$)



JJA (CAM5)

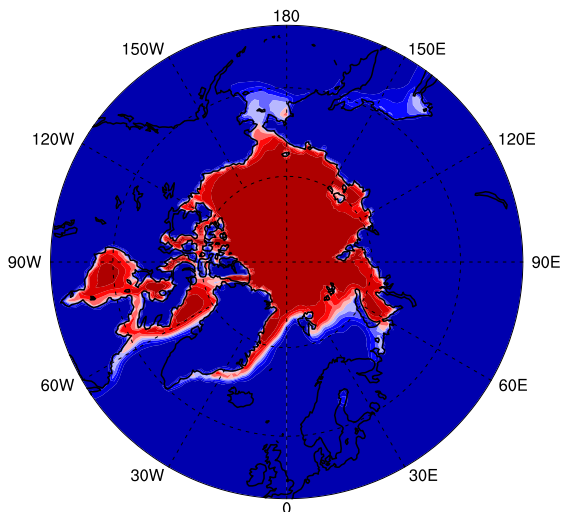
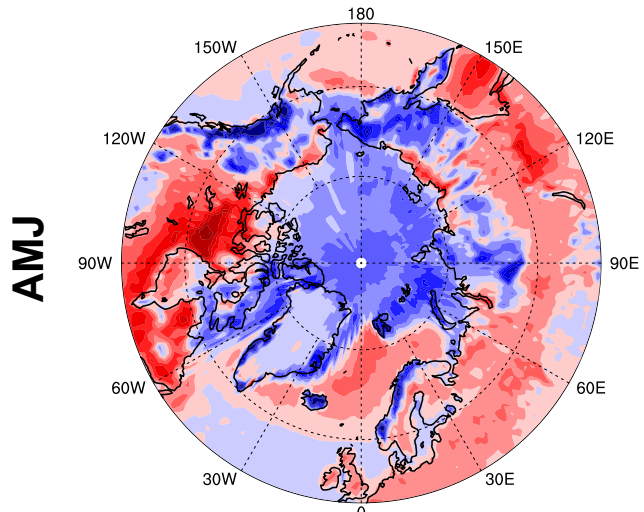
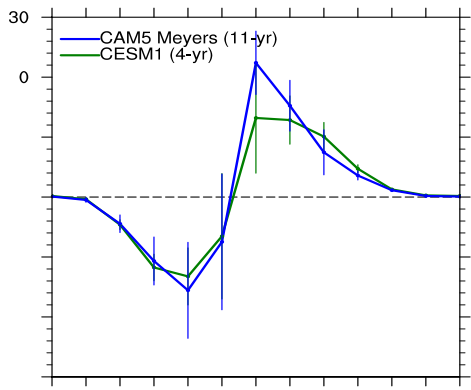


Snow depth (cm)



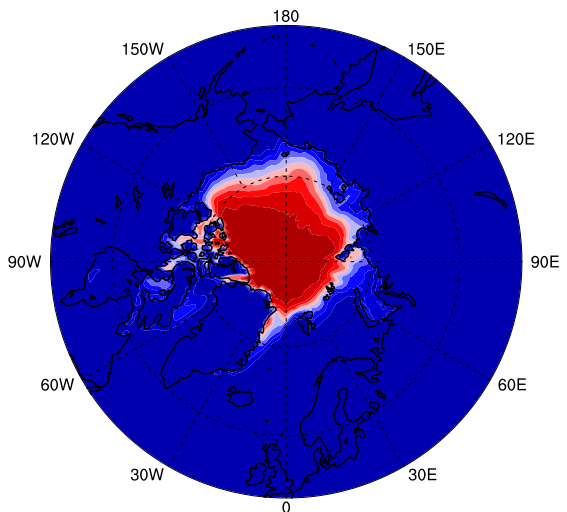
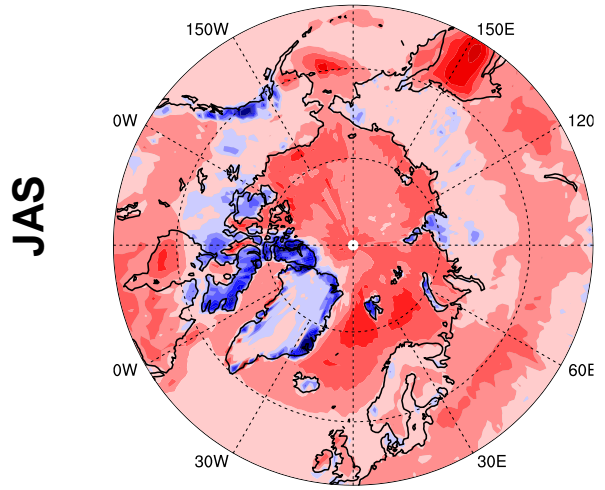
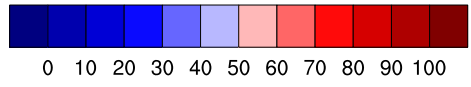
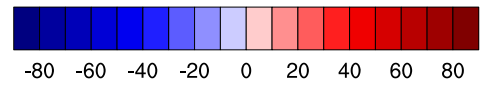
Q: Why does CAM5 clearsky SW over water swing from too low in spring to too high in summer?

A: Snow on ice albedo too high; albedo too low over ocean (Also, CERES clearsky retrieval biases?)

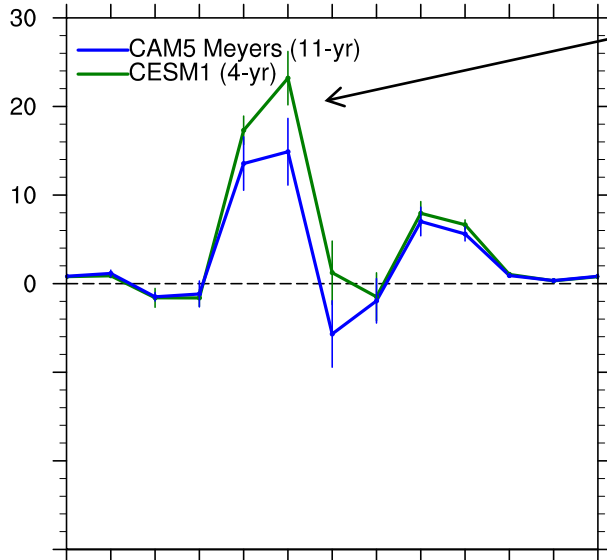
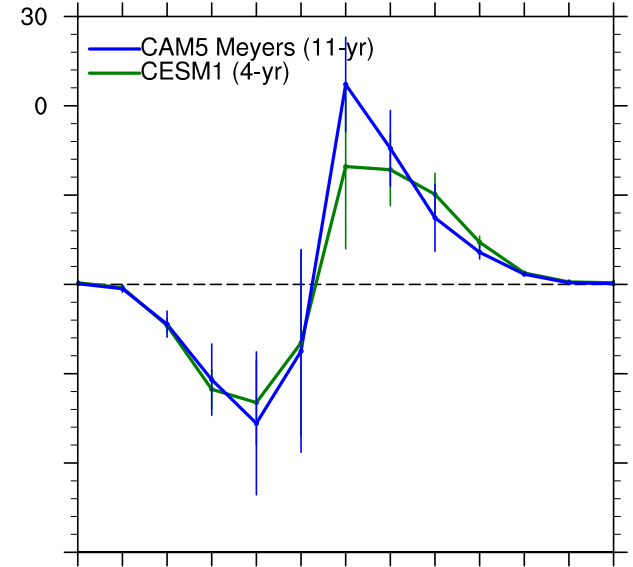
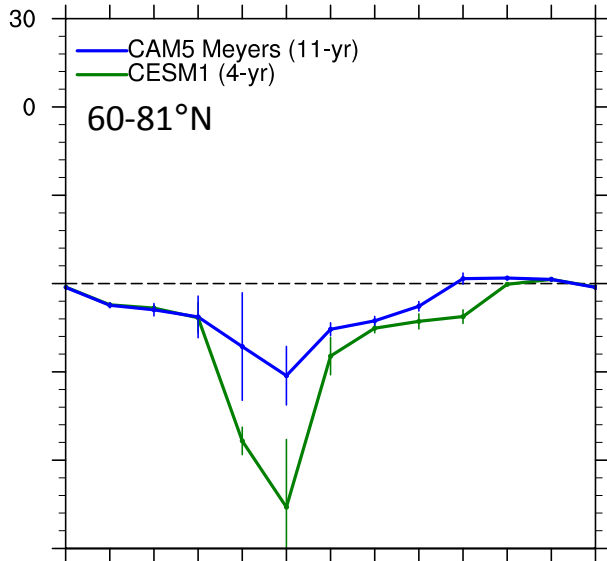


Clearsky TOA SW Bias (CAM5 – CERES)

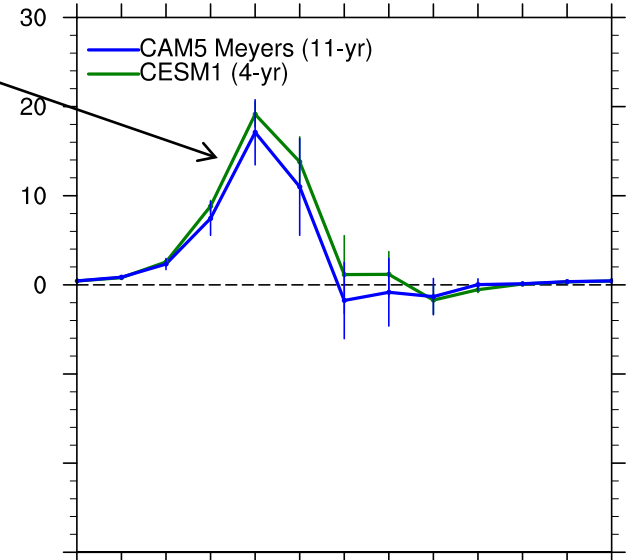
Sea ice cover (%)



CAM5 Cloud forcing biases tend to compensate for Clearsky biases

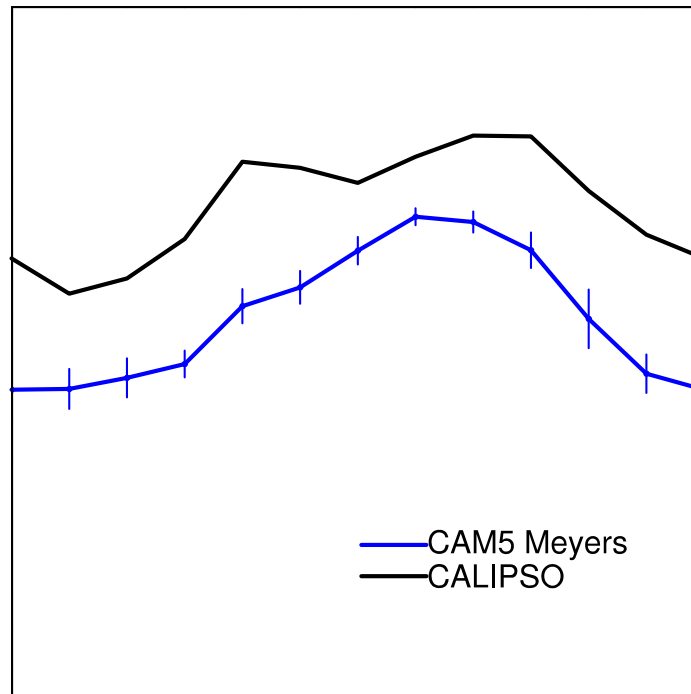


Q: Why do CAM5 cloud forcings have positive biases in spring/summer (clouds allowing too much SW)?



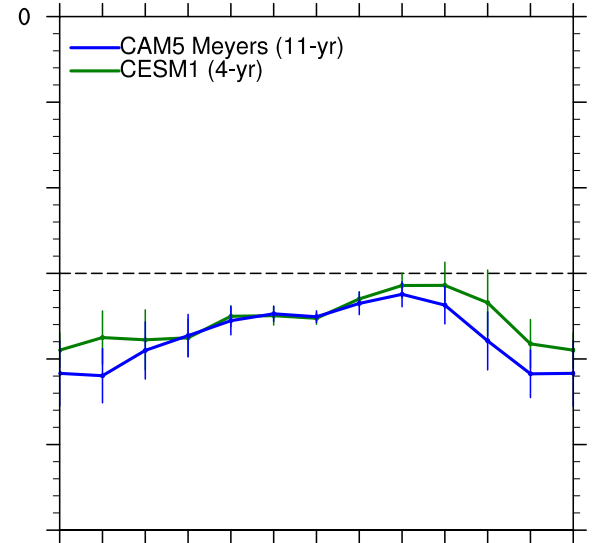
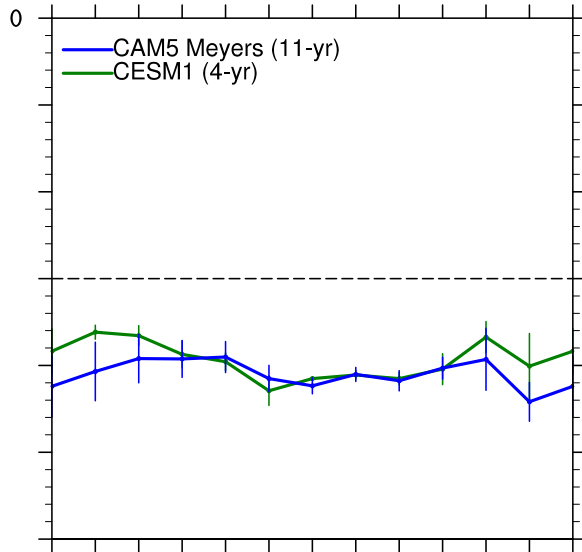
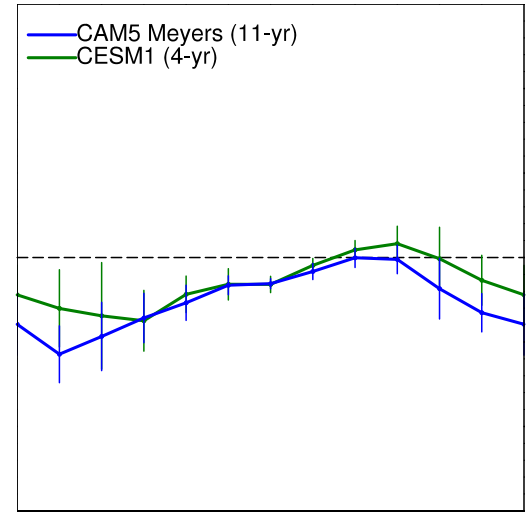
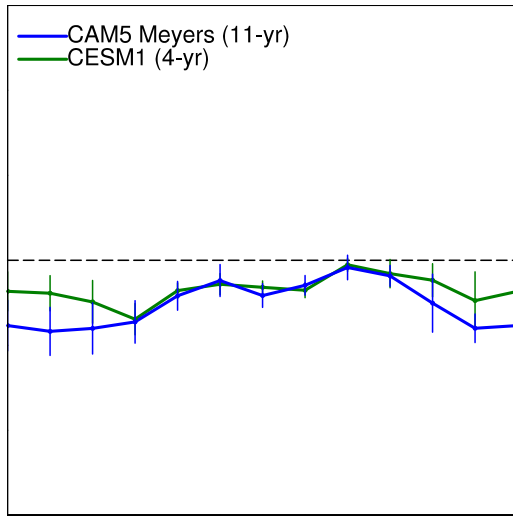
Q: Why do CAM5 cloud forcings have positive biases in spring/summer (clouds allowing too much SW)?

A: Not enough clouds in the Arctic.



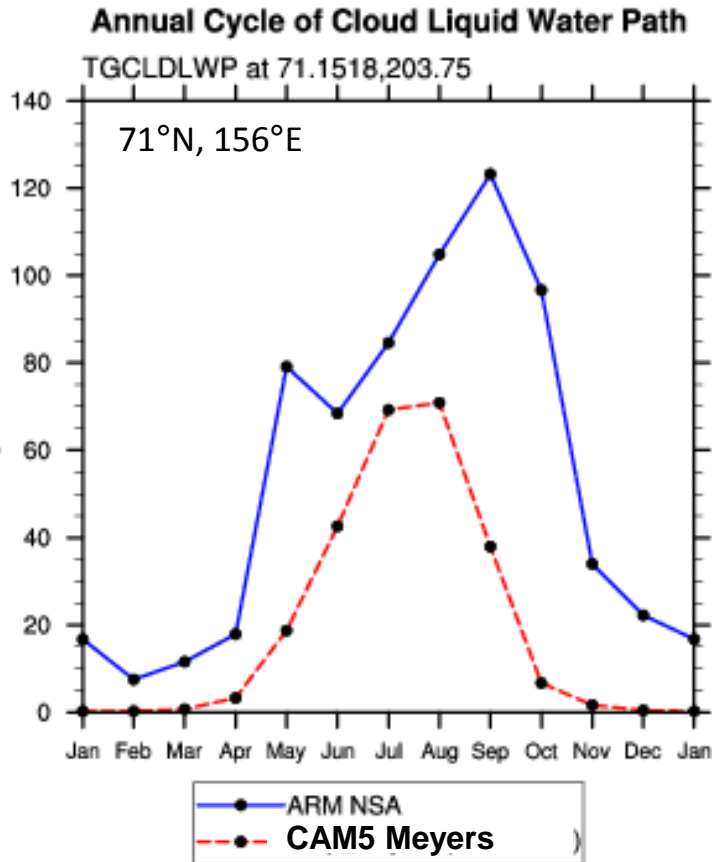
Note: a snow treatment fix recently implemented in COSP caused a reduction of CAM5 winter clouds

CAM5 OLR is consistently $\sim 10 \text{ W m}^{-2}$ too low

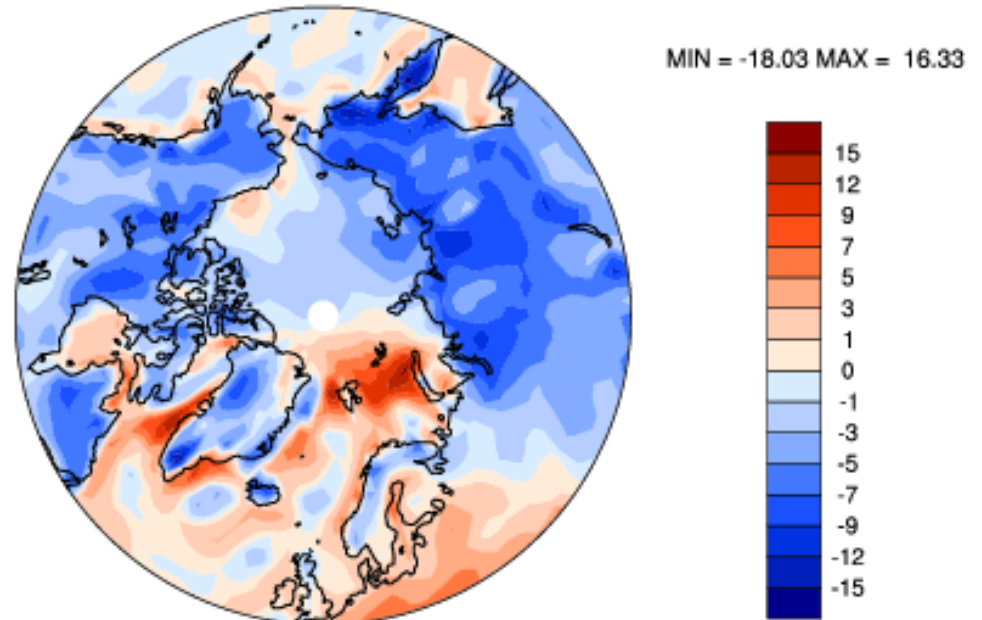


Q: Why is CAM5 Winter OLR too low?

A: Not enough winter clouds in CAM5, and LWP is too low; allows too much radiative cooling; surface T gets too cold



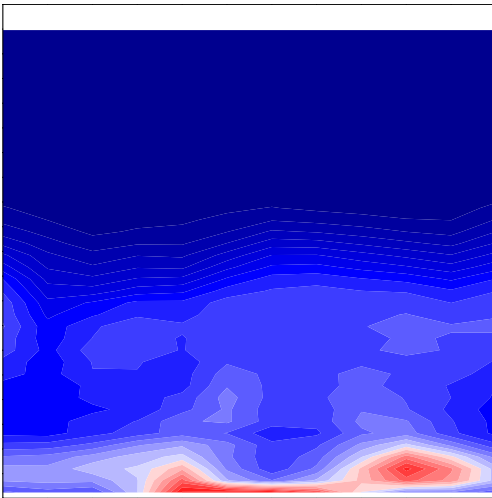
DJF Temperature Bias (CAM5 Meyers – NCEP)



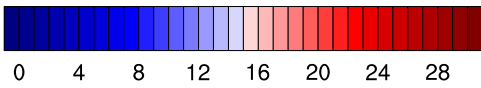
Q: Why is CAM5 Summer OLR too low?

A: Too many clouds at higher altitudes

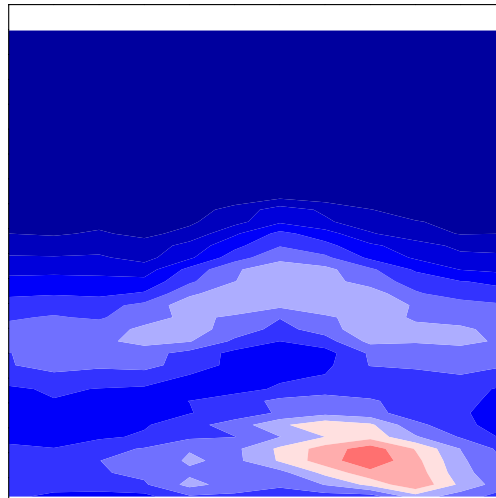
CALIPSO



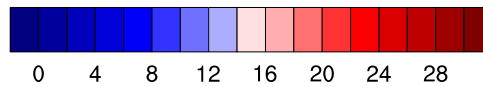
Cloud percent



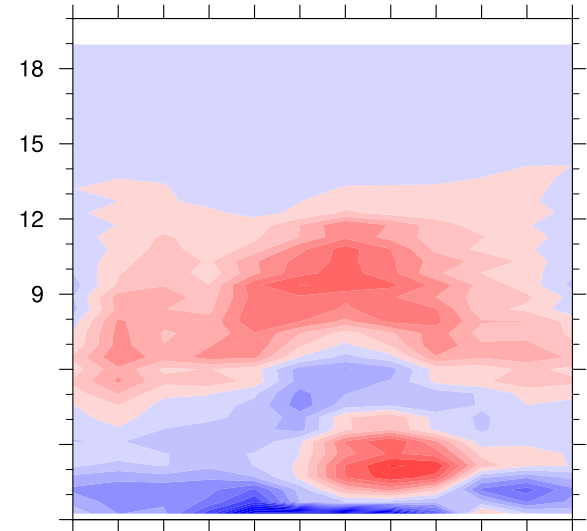
CAM5 Meyers



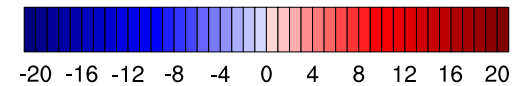
Cloud percent



CAM5 Meyers - CALIPSO

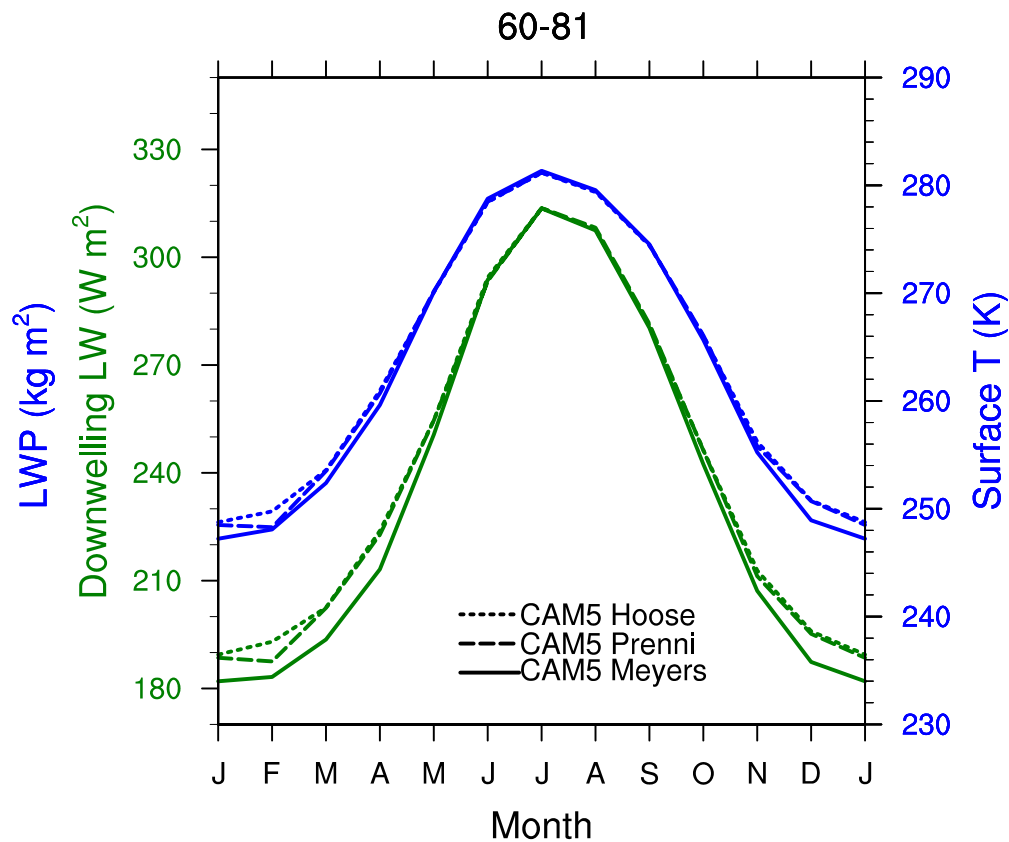
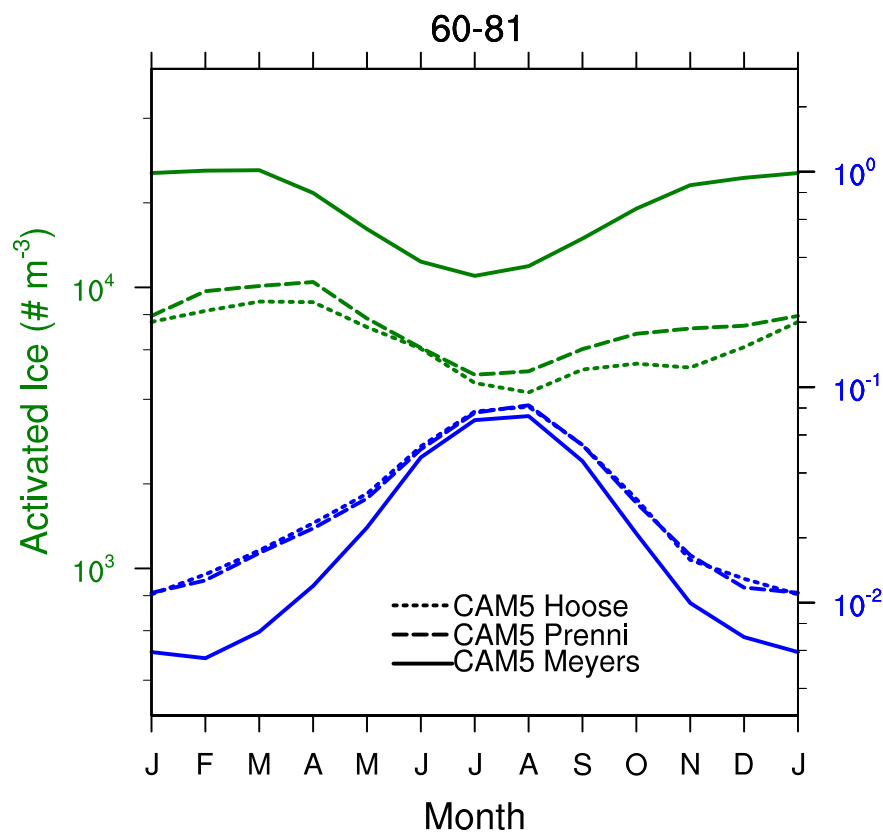


Cloud percent

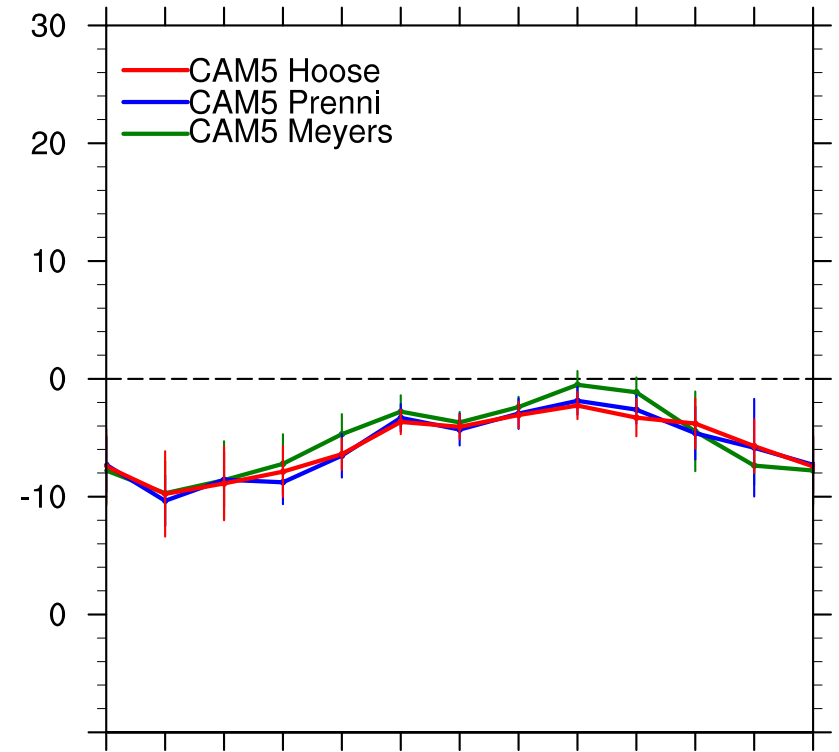
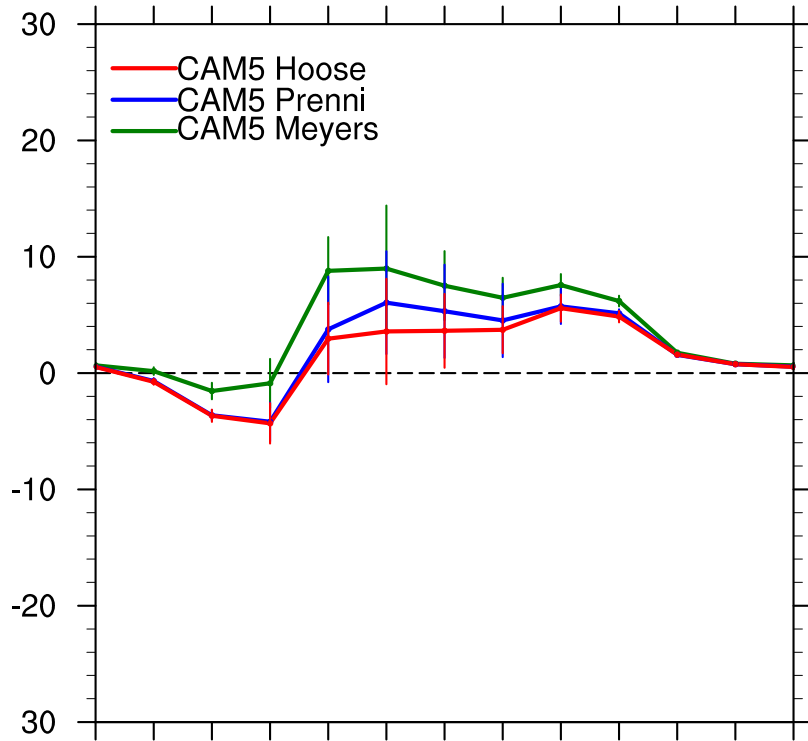


As expected, new mixed-phase ice nucleation schemes:

- Reduce activated IN
- Increase LWP
- Increase Downwelling LW
- Increase Winter T_s



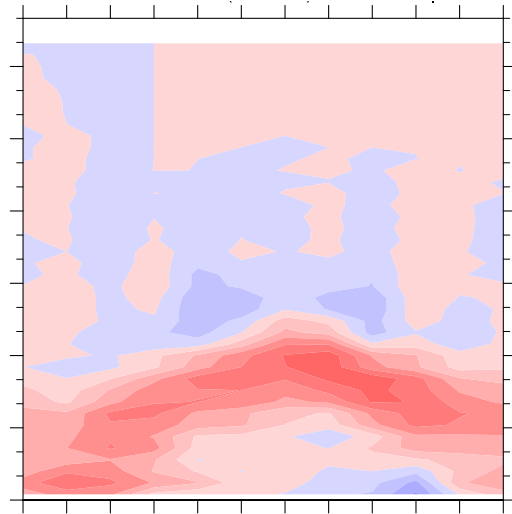
However, TOA radiation biases remain (SW improves slightly). Why?



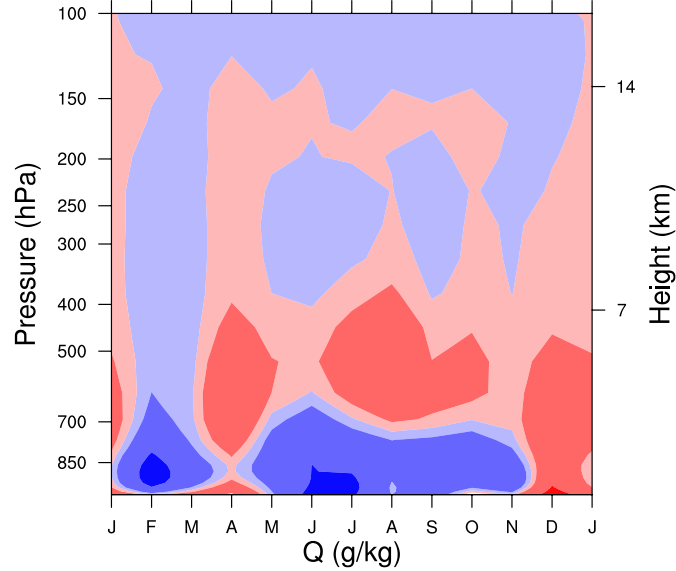
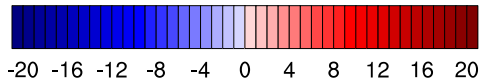
Q: Why aren't TOA radiative fluxes improved?

A: Excessive clouds and humidity at upper (colder) levels

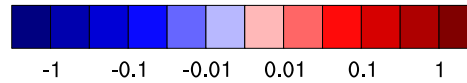
CAM5 Prenni –
CAM5 Meyers



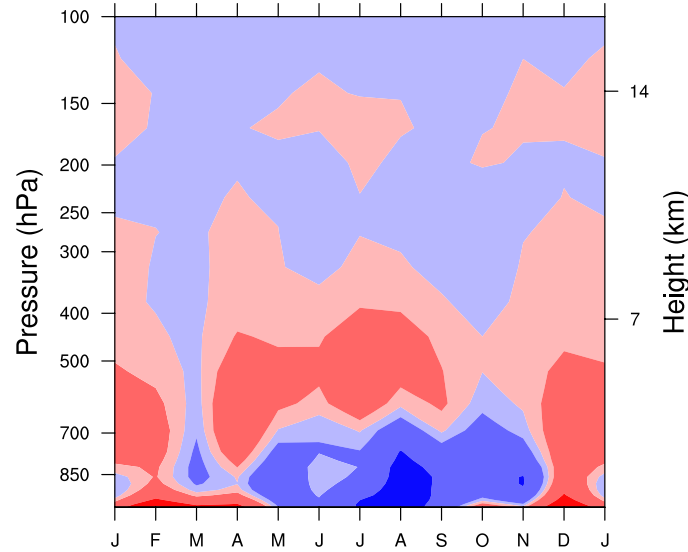
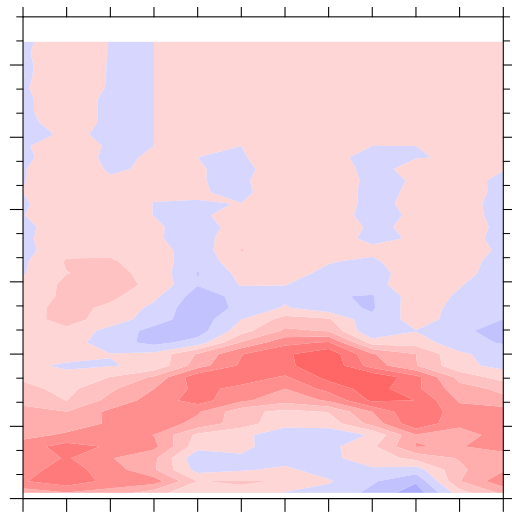
Cloud percent



Q (g/kg)



CAM5 Hoose –
CAM5 Meyers



Summary

- **CAM5 Net TOA SW is generally within 10% of CERES, however:**
 - **CAM5 has insufficient clouds/LWP**
 - **This is somewhat balanced by model snow/ice/water albedo biases (or CERES clearsky retrieval issues)**
- **CAM5 OLR is consistently ~10% too low**
 - **Winter Ts too cold due to CAM5 LWP being too low**
 - **Too many clouds at 300-700**
- **New mixed-phase ice nucleation schemes have pros/cons:**
 - **Increased (improved) LWP, LW_{down} , surface T**
 - **Even more excessive water vapor, clouds at higher levels**
 - **E.g. Arctic radiative budget redistributed but TOA not improved**
 - **What is the cause of persistent radiation biases in the Arctic? Moisture/heat transport? Cloud microphysics/macrophysics?**